GoDetect™ Version 8 Release Notes

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Summary
GoDetect™ Version 8 is the newly released version with the latest machine and vision learning architecture to automatically determine a reaction with the ESD machine. GoDetect™ View is not yet updated to include machine learning but relies on the users determination with facilitated video review and logging software. Safety Management Services, Inc. developed GoDetect™ and use of the software is subject to the Terms of Use.

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1. Introduction

GoDetect™ is used to automatically determine reactions with small-scale sensitivity testing (SSST) equipment by more than a dozen national and industry laboratories.

GoDetect™ ESD uses a Phantom camera and a software algorithm to automatically determine if a reaction has occurred. This reaction detection algorithm utilizes state-of-the-art image-based machine-vision with the resnet34 architecture from fastai (https://www.fast.ai/) and pytorch (https://pytorch.org/). Development of the model included collecting high-speed video of the ESD testing while simultaneously collecting the CO ppm given off by the sample. Over 800 tests were completed simultaneously measuring CO ppm levels and high-speed images with multiple substances at multiple energy levels. The image-based model was then trained to yield the categorical result of the level of CO ppm for each image with a little over a half of the tests used for training and the other half for model validation.

GoDetect™ View also uses a Phantom camera and software but requires user determination to make a reaction classification. In the future, machine vision can also be used to facilitate automatic reaction determination for these machines such as the ABL Friction and MBOM Impact.

2. Computer Requirements

In order to run GoDetect™ on your Windows computer, you'll need to install Docker Desktop. Installation and running of Docker Desktop has the following requirements (further details here: https://docs.docker.com/docker-for-windows/install/):

- Windows 10 64-bit: Pro, Enterprise, or Edu-

cation (Build 15063 or later).

- Hyper-V and Containers Windows features must be enabled. The following are required to successfully run Client Hyper-V on Windows 10:
  - 64 bit processor with Second Level Address Translation (SLAT)
  - 4GB system RAM
  - BIOS-level hardware virtualization support must be enabled in the BIOS settings

3. GoDetect™ ESD Model Details

Several plots that profile the data used in training and validating the model are shown here. The substances used in training of the model were intended to yield a good representation of various substances that would be tested with the ESD machine. The model has been validated with the same substances as well as with substances not part of the training set showing that this base model is capable of reproducing results consistent with a gas analyzer. When training the model, the CO ppm result was categorized in that anything less than 1 ppm is in the 1 ppm category, CO ppm levels from 1-5 ppm are in the 5 ppm category, 5-20 ppm are in the 20 ppm, and anything over 20 ppm is in the 50 ppm category. These levels represent the 'No reaction', 'Minor', 'Significant', and 'Extreme' reaction levels that are reported on the GoDetect™ detection page of the web app.

Figure 1 shows the 4 categories of the level of CO ppm given off from the tested substances with the corresponding natural log of the capacitance in microfarads at the test level. This plot is included here to show that training and validation of the model included a wide range of spark energy levels and resulting CO ppm values. All testing was completed at 5000 Volts.

Figure 2 shows the substances tested and the corresponding capacitance value in natural log units of the microfarad value. This plot is included here to show where in the energy spectrum each substance was tested to yield the CO ppm level for use in the training and validation

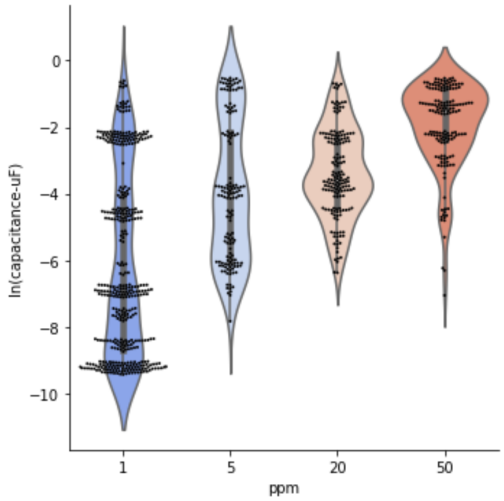


Figure 1: GoDetect™ model training and validation tests as a violin plot with the 4 categories of the level of CO ppm given off with the corresponding natural log of the capacitance in microfarads at the test level. This plot shows that training and validation of the model included a wide range of spark energy levels and resulting CO ppm values.

of the model. Note that substances were tested to yield a result from consistent no reaction (no evolution of CO) to reaction where the probability of that reaction ranged from near zero to near 100 percent. As such, with some materials, the range over which the testing was completed is not the entire range of the machine. Additionally, in the case of the empty (no substance present) and the white and black sand, the entire range of the machine was tested to properly train and validate the model to identify no reactions. Note that in all but a few of the cases tested at the highest energy levels with the inert substances, detection of CO with the CAI gas analyzer was not observed.

Figure 3 shows the substances tested versus the ppm values of carbon monoxide measured during the testing. This plot is included to show that all of the substances were tested from no reaction to a significant reaction to properly train and validate the model.

The accuracy measure of the model is based on the false positive and false negative rates. That is, the rate at which an actual no-go reaction

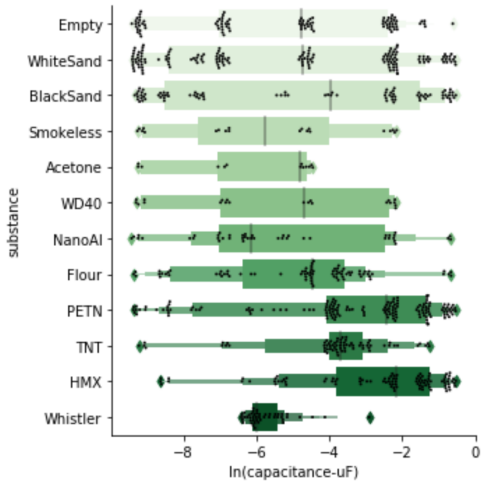


Figure 2: Box plot showing the substances tested and the corresponding capacitance value in natural log units of the microfarad value. All testing was completed at 5000 Volts.

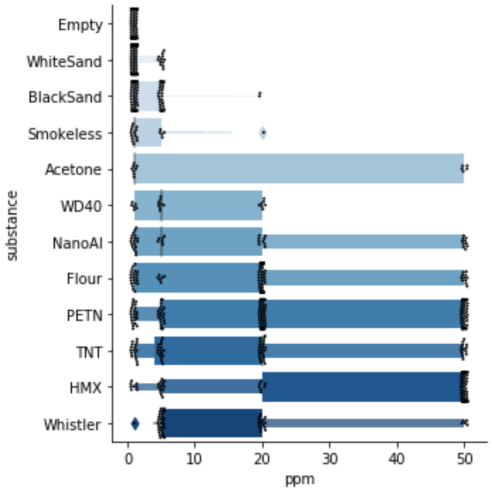


Figure 3: Box plot showing the substances tested versus the ppm value.

is labeled as a go by the model (false positive) and the rate of a go reaction labeled as a no-go (false-negative) is low at 5% for the training and validation sets. The confusion matrix for the validation trials is shown in Figure 4. This shows the majority of trials were predicted accurately by the model and that the false positive and false negative rates of the validation set was 14/191 and 18/220, respectively with a reaction threshold of 1ppm CO. The rates for the training set were lower. The number of tests in the training set was 452 for a total of more than 800 tests for the training and validation sets.

Two substances, not included in the model development, were tested to further evaluate the model with results that mimicked the false positive and negative results of less than 5%. The two substances were PBXN containing flakes and a substance containing aluminum hydride. Results closely matched the CO ppm determined values. With the above results, it's likely that the model will yield satisfactory results for a large number of substances and their derivatives. If the model is not performing well for a specific substance, the model can be retrained and/or customized. See the Model Retraining section below.

4. GoDetect™ ESD Instructions

These are the steps to run GoDetect™ version 8.

1. Setup the camera such that it is secured and pointed toward the needle and electrode with the proper extension tubes and the proper f-stop (16 for GoDetect™ ESD ver 8).
    - Make sure the iris fstop is working by looking into the lens to see the iris diameter change. After setting it to f/16, no need to change the fstop during testing.
2. Open PCC software on the computer and connect to the camera. If you have problems connecting, its likely due to the ip address. You can change that to what the camera needs by following Phantoms instructions (like going to 'view network connections' and then updating the address in the IP4 protocol).
    - Focus the camera on the lowered needle and area where the sample will be placed. Click the low-light button and perhaps lower the fstop or use a light if to see the image. You should see a clear and focused image of the needle and sample holder. The entire metal electrode should be visible in

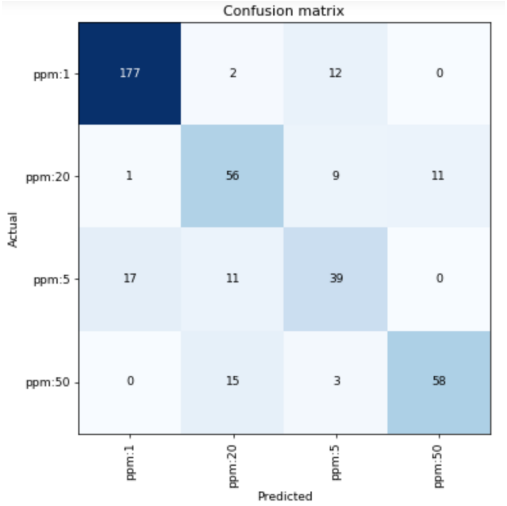
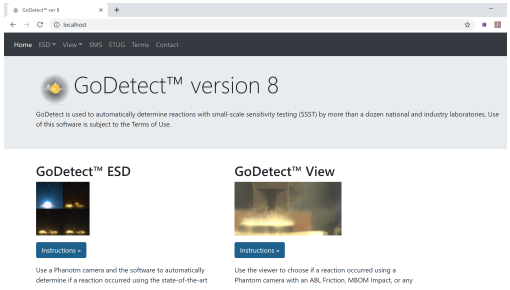


Figure 4: Confusion matrix for the validation set.

the frame with the needle in the center. Unclick the low-light button. Set the fstop to f/16.

- Set the resolution to 256 x256.
- Set the frame rate to 5000 frames per second with the maximum exposure time.
- Perform a session reference by clicking the CSR (Current Session Reference) button.

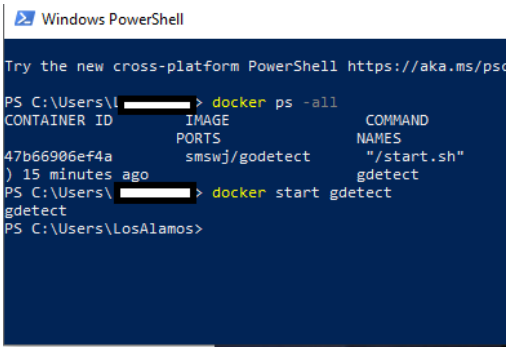
3. Verify that the trigger is functioning.
   - Ensure that the coax cable from the BNC connector on top of the ESD machine is connected to the BNC connector on the camera labeled as “trigger”. Manually trigger the camera in the PCC software. The red light will light up on the back of the camera indicating the camera is recording. Run the ESD machine at the lowest energy level. Once the ESD machine has dispensed the energy through the needle, the red light on the back of the camera blinks and turns off and in the PCC software the trigger button that was previously green is now grey. This confirms that the current trigger is functioning.
4. Open the ABL ESD shortcut folder on the desktop.
   - If its not there create one by navigatig to C:\Users \yourspecificidname \GoDetectData \ABL ESD and right clicking on the folder to create a shortcut and then moving it to the desktop. The view shortcut folder should be set to C:\Users \yourspecificidname \GoDetectData \View.
5. Inside the ABL ESD folder, create a new folder and name it the material being tested. This folder name will hold all of the cine files and will be included in the dropdown so you can customize the name for example PETN-1 (with the -1 meaning testing for this day or week).
6. After setting up the folder(s) and the camera, in the PCC software click on the Continuous Recording tab.
   - In that menu, click ’Browse’ and navigate to the desired folder that you just created.
   - Type Run@4.cine in the file name box. The software will create a new cine file each time the camera is triggered with the first one labeled Run0001.cine. The prefix for all the files does not have to be named ’Run’.
   - In the Save Cine dialogue, click the drop down menu for Range Option and choose User Defined and type [-10,30].
   - Click save.
   - Click the activate check box.



7. Launch the GoDetect™ GUI by opening a browser and typing ’localhost’ in the address bar. If there is an error and the GUI

webpage doesn't appear complete the following 3 steps:

(a) Verify that docker desktop is running.You should see a whale with containers on its back in the icon tray which says 'Docker Desktop is Running' when you mouse over it. If not, start Docker Desktop, by searching for Docker Destop in the Windows bar and then starting it by opening a Windows Powershell and typing 'docker start gdetect'. If the result printed in the screen is like that below, the gdetect container was started successfully.



(b) If there was an error, when typing 'docker start gdetect' into the Windows powershell, the docker container may have been deleted and you'll need to restart the gdetect container by typing the following in the Windows Powershell prompt: docker run -d -v C:/Users/<yournameid>/ GoDetectData: /app/GoDetectData -p 80:80 –name gdetect smswj/godetect.

(c) Retry launching the GoDetect™ GUI by opening a browser and typing 'localhost' in the address bar.

8. Complete the test with the substance and click the reload button such that the http://localhost/godetectesd page reloads and it automatically pulls up the video of the event.

9. To change materials, create a folder for the new material as described above in Step 5. Now open PCC. Click on the Continuous recording drop down menu. Uncheck the Active box. Click Browse and navigate to the new material folder and name it Run@4.cine (or Event@4 or Test@4, etc) with the same user definitions of [-10, 30] and Save and then Check the Active box under the Continuous recording menu.

10. Occasionally backup the database used by the software by typing the following command into the Windows Powershell: docker cp gdetect:/app/GD_test.db GoDetectData/GD_test_backup.db

11. Further details on using the GoDetect™ GUI are on the user interface on the respective instructions page.

5. GoDetect™ ESD Model Retraining

As described above, the model was trained, validated and tested with more than a dozen representative substances to yield accurate results for determination of the onset of reaction consistent with results of gas analysis of carbon monoxide. However, further training and validation is expected to occur to include additional substances and further validate the gas evolution concentration at higher energy levels to yield more accurate probability curves for the significant and extreme reaction levels. See Figure 5 and the associated Section 6.

In addition, custom models can be trained for a substance that is unique in its behavior relative to the standard substances used here. For such scenarios, a custom model can easily be developed and deployed. If your results are unexpected or are not making sense as verified with a gas analyzer or other objective determination, contact us and we will work with you to either update or customize the model to your requirements. We would need the images from the test (instructions on retrieving those will be provided) and the labels such as the CO ppm for each test.

6. Characteristic Curves or Probit Plots

The characteristic curve or probit plot relates the energy of the impetus to the probability of a reaction event. Such a curve can be easily generated by first opening the SMSPROBITTemplate_V1.xls file under the GoDetectData folder. The table generated in the GoDetect™ web application for either ESD or View showing the setting, number of Go's, and number of Trials is then simply highlighted with the mouse and then copied into the excel sheet. The setting can then be modified to give the appropriate number value and the probit curve determined and plotted by clicking the Calculate button.

Note that GoDetect™ version 8 for ESD includes probability determination for Minor, Significant, and Extreme reactions correlated with the amount of CO given off from a small test sample. Using those probability determinations, can be used to calculate characteristic curves or probit plots for those same reaction levels. An example of such a plot for PETN is in Figure 5. The variability seen at higher energy levels is due to the limited data at those higher energies. This feature represents an extension of the methodology typically used in completing Small-Scale-Sensitivity Testing (SSST). The data to compete a similar plot is available in this release of GoDetect. Automated generation of the plot is expected in an upcoming version.

7. GoDetect™ View Instructions

The instructions for using GoDetect™ View are very similar to those of GoDetect™ ESD that are listed in the previous section.

1. Secure the camera to the base, attach any necessary extension tubes, and attach the lens to the camera.
2. Setup the camera such that the view of the camera can clearly see the area of interest for the machine used.
    - The material should be in focus and the area around the material should be visible.
    - Camera setup and focusing may be easier with auxiliary light and/or a low frame rate like 24 and a very long exposure.
    - For reaction determination involving jetting, you should have the edge of the anvil or the edge of the bulkhead in view.
        - The recommended frame rate for the MBOM Impact to identify jetting incidents of 1000 in/sec or greater is 2000 fps.
        - The recommended frame rate for the ABL Friction to identify jetting at the same speed is 1500 fps.
        - See additional resources on the ET Users Group website (https://www. etusersgroup.org /library /reaction-detection-discussion/).
    - The recommended resolution is 512 x 256 or 256 x 256 depending on the machine.
    - The fstop on the camera should be set to an appropriate value so that the test material and function of the machine can be seen.
3. Verify that the trigger is functioning.
    - Ensure that the coax cable from the trigger cable from the machine is connected to the BNC connector on the camera labeled as "trigger".
    - Manually start the recording of the camera in the PCC software. The red light will light up on the back of the camera indicating the camera is recording.
    - Run the machine as if completing a trial.
    - The camera should have triggered, and the red light on the back of the camera blinks and turns off and in the PCC software the trigger button that was previously green is now grey. This confirms that the current trigger is functioning.
4. Create the appropriate folders.

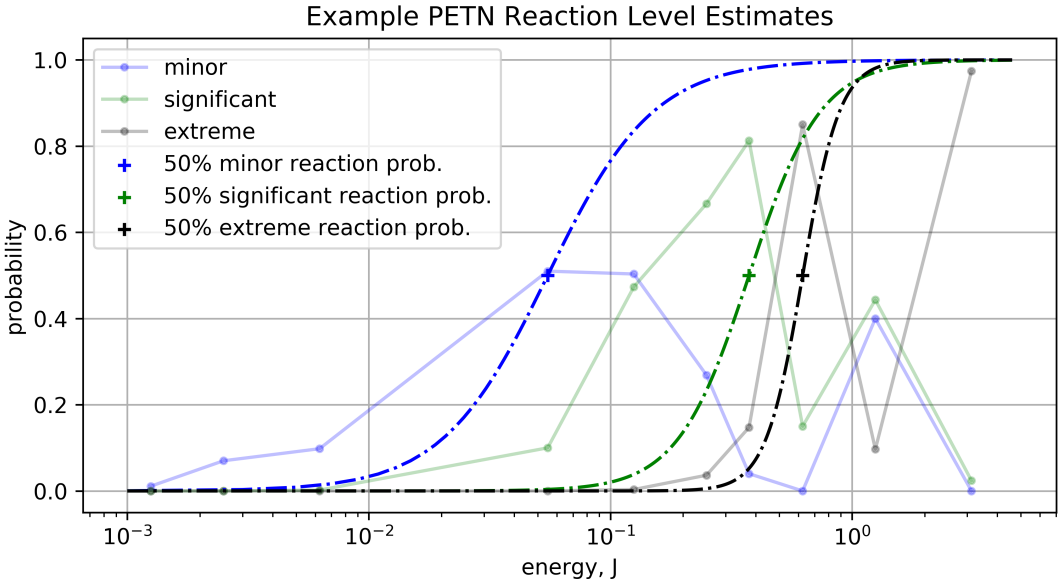


Figure 5: Example plot showing future implementation to determine reaction probabilities at multiple reaction levels. The underlying curves are the average probabilities for each reaction level for each tested energy for PETN. The cumulative probability curves is a fit based on the peak heights and widths of those probability curves. Further details and information to be released in a software update.

- If testing PETN on the ABL Friction machine, make sure there is a PETN folder in an ABL Friction folder in the View folder in the GoDetectData folder:
  - e.g. C:
    Users
    yourspecificidname
    GoDetectData
    View
    ABL Friction
    PETN.
  - If there isn't a PETN folder in the ABL Friction folder, create one.
- For other machines, first create a folder with the machine name within the View folder

5. In the PCC software click on the Continuous Recording tab.
   - In that menu, click 'Browse' and navigate to the desired folder that you just created in the substance folder for that machine.
   - Type Run@4.cine in the file name box. The software will create a new cine file each time the camera is triggered with the first one labeled Run0001.cine. The prefix for all the files does not have to be named 'Run'.
   - In the Save Cine dialogue, click the drop down menu for Range Option and choose User Defined and type the [-start,finsih]. Where the start and finish numbers are determined by you the user to make sure that the event is captured sufficiently witout saving more the 200 frames typically.
     - For example, if the trigger event is typically 10 frames ahead of the event then it is recommended you save frames -20 to 30. You will enter this in the bottom of the save file window prior to starting testing.
     - Click save.
     - Click the activate check box.

6. Complete the test with the substance and machine and click the reload button such that the http://localhost/godetectview page reloads and it automatically pulls up the video of the event. Note that there is a delay as the images are extracted from the cine file for display. The delay can be 10-20 seconds depending on the number of images in the cine file. See further details below.
7. Occasionally backup the database used by the software by typing the following command into the Windows Powershell: docker cp gdetect:/app/GD_test.db GoDetectData/GD_test_backup.db

8. GoDetect™ Cloud Updates

Program updates are available from the Docker Hub repository of the GoDetect application in the Cloud. It is a private repository for which you can be granted access. To get access, purchase GoDetect and sign up for a free account on Docker Hub. Here is the link to get an account: https://hub.docker.com/signup. Once you have a Docker Hub account id, send an email to cguymon[at]smsenergetics.com with your id. Read access to the smswj/godetect repository will be granted and you can check for and download the latest software update. Directions for doing so are below:

- Download Docker Desktop if it's not currently on your machine. Section 2 describes the computer requirements.
- If performing an update:
    1. Backup the GD_test.db database file by copying it to your file system from the container's filesystem. Type in the following command on the Windows Powershell prompt: docker cp gdetect:/app/GD_test.db GoDetectData/GD_test_backup.db. Verify that the GD_test_backup.db is now in the GoDetectData folder on your c drive under the Users folder and then your username folder.
    2. Now update the GoDetect program by simply typing 'docker pull smswj/godetect' after logging in to docker (docker login or sign in on the docker icon in the system tray) and choosing the smswj repository in the system tray when mousing over the docker whale icon.
    3. Now run the new downloaded docker image by typing the following command into the Windows Powershell: docker run -d -v C:/Users/<yournameid>/ GoDetectData :/app/GoDetectData -p 80:80 –name gdetect smswj/godetect
    4. Now restore the backed-up GD_test.db database file to the containers directory by typing the following command into the Windows Powershell: docker cp GoDetectData/GD_test_backup.db gdetect:/app/GD_test.db
- For a virgin or 1st time install:
    1. Run this command in the windows power shell after downloading and installing Docker Desktop: docker run -d -p 80:80 –name gdetect smswj/godetect.
    2. Now copy the GoDetect folder over to the Users /username directory by running this command: docker cp gdetect:/app/GoDetectData GoDetectData. Verify that files were copied from the container to the host by checking that C:/Users /username /GoDetect data exists and there's data in it.
    3. Stop the container and remove it with: 'docker stop gdetect' and then typing and entering 'docker rm gdetect '
    4. Then run the full command: docker run -d -v C:/Users/<yournameid>/ GoDetectData: /app/GoDetectData -p 80:80 –name gdetect smswj/godetect. This full command ensures that files you store under the GoDetectData can be seen by the program.

9. Terms of Use

By using this application of GoDetect™, you agree to the following terms:

- You will not reproduce this software application or the files associated with its operation for commercial use.
- You will not share the software application or any of the files associated with it with anyone outside your immediate group.
- You will share any improvements desired or completed with the manufacturer, Safety Management Services, Inc.
- You will not modify any of the files defining the function or operation of GoDetect™ version 8 without coordinating such efforts with Safety Management Services, Inc.
- You will not hold Safety Management Services, Inc. responsible or otherwise accountable for the consequences of use of this software including when used to make safety determinations.